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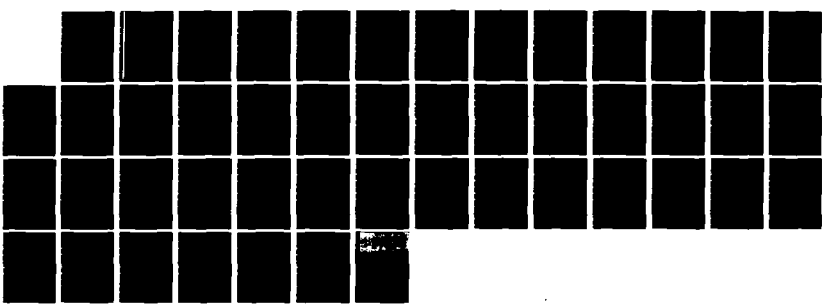

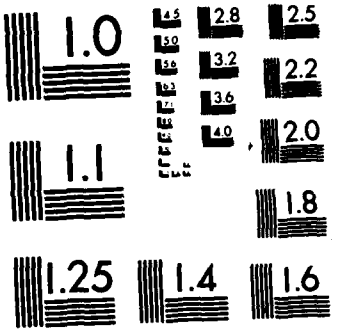

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PILOT FIELD TEST OF MULTIVISCOSITY/SYNTHETIC ENGINE OIL IN ARMY COMBAT/TACTICAL VEHICLES AT FT. BLISS, TX

INTERIM REPORT
AFLRL No. 160

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Military lubricant orders for combat and tactical equipment specify use of a single-viscosity grade lubricant. The use of this type oil results in frequent oil changes caused by seasonal climatic temperature changes. Since the development of a multiseasonal MIL-L-2104 tactical/combat engine oil has been one of the major thrust areas for U.S. Army Mobility Equipment Research and Development Command (MERADCOM)(currently U.S. Army Belvoir Research and

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20. ABSTRACT (Continued)

Development Center), a pilot fleet test using multiviscosity diesel engine oils was initiated at Ft. Carson, CO in January 1977 and later expanded to Ft. Lewis, WA in 1978-1979. Based on the successes achieved with these two tests, MERADCOM then decided to determine the effects of multiviscosity diesel engine oil on equipment readiness and proper engine lubrication/protection during very warm weather operations. To this end, a pilot field test was initiated in August 1980 at Ft. Bliss, TX involving E and H Troops of the 3rd Armored Cavalry Regiment. The test utilized M60A1 tanks and M113A1 Armored Personnel Carriers (APC). Although the consensus among the commanding officers, maintenance, and operating personnel was that a 0W-20 multigrade oil or a 10W-30 multigrade oil would not adequately lubricate/protect the tactical/combat engine at the warm ambient temperatures involved, the test oils appeared to function in a satisfactory manner. Extended operations (through October 1981) of the test and control vehicles in ambient temperatures up to 37.8°C (100°F) did not result in any observed adverse effects on the equipment. Also, there was no apparent change in the engine failure/removal rate. The scope of this test was very limited and precluded a recommendation that the test oils and others of like properties and qualities be used in this type of service.

FOREWORD

This report was prepared by the U.S. Army Fuels and Lubricants Research Laboratory (USAFLRL) located at Southwest Research Institute, San Antonio, Texas, under Contract No. DAAK70-82-C-0001. The work was sponsored by U.S. Army Belvoir Research and Development Center, Fuel and Lubricants Division, Materials, Fuels and Lubricants Laboratory, Fort Belvoir, Virginia and covered the period from August 1980 to October 1981. The Project Monitor and Contracting Officer's Representative was Mr. F.W. Schaekel, Belvoir R&D Center, STRBE-VF, Fort Belvoir, Virginia.

Acknowledgment is given to Messrs. M.E. LePera, Belvoir R&D Center, STRBE-VF, Fort Belvoir, Virginia, and S.J. Lestz and R.A. Alvarez of USAFLRL for their participation, encouragement, and suggestions. Special acknowledgment is given to Mr. Frank Balderson, Corpus Christi Army Depot of Corpus Christi, Texas for assistance provided throughout the program.

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I. INTRODUCTION

Since the late 1960's, the Army has used synthetic multiviscosity engine oils for lubrication of equipment in arctic regions.(1-6)* Based on the successful arctic experience, continued efforts investigating the use of conventional and synthetic multiviscosity engine oils were incorporated into the Army's lubricant research and development programs.(7-10) It is believed that the use of a single "year round" lubricant could eliminate seasonal changes (11,12), possibly extend the oil drain interval, and provide a greater degree of combat readiness.

Presently, military lube orders for combat and tactical equipment specify use of single-viscosity grade oils. Use of single-viscosity grade oils results in frequent oil changes caused by seasonal and climatic temperature changes without regard to the condition of the oil being changed. To minimize the number of oil changes and the disposal of significant quantities of otherwise useful oil, attempts have been made to use single-viscosity grade oils at temperatures lower than those recommended by applicable lube orders. This practice, however, resulted in operational problems and equipment malfunctions. Therefore, the U.S. Army Mobility Equipment Research and Development Command (MERADCOM)(currently U.S. Army Belvoir Research and Development Center) initiated a pilot field test at Fort Carson, CO where M60 battle tanks typified the problems mentioned above. The purpose of the field test was to evaluate the capability of MIL-L-46167 arctic oil (OEA) to provide an interim solution to the lubrication problems and to develop data to be used as a basis for developing multigrade engine oils for Army tactical and combat equipment. Also, it was desired to generate supplemental information covering the use of OEA lubricant over expanded temperature ranges. This test was later expanded to include Fort Lewis, WA.(13,14)

Because the tests conducted at Ft. Carson and Ft. Lewis produced results

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* Underscored numbers in parentheses refer to the list of references at the end of this report.

which clearly indicated that the synthetic lubricants had elevated test-vehicle readiness, especially in the colder months, and had no adverse effects on the equipment, MERADCOM initiated a limited pilot field test at Ft. Bliss, TX, utilizing tactical/combat vehicles of the 3rd Armored Cavalry Regiment. The purpose of this limited pilot field test was to determine the effect of multiviscosity engine oils on equipment readiness and proper engine lubrication/protection during very warm weather operations. Ft. Bliss and the 3rd ACR were chosen because they were located in the required severe warm weather environment.(15) Background information about the test is provided in Appendix A.

II. EQUIPMENT AND TEST PROCEDURES

The initial equipment provided by E and H Troops, 2d squadron, 3rd ACR with identification numbers and the oil with which each was lubricated are shown in Table 1.

TABLE 1. DESCRIPTION OF TEST VEHICLES-PHASE I

Vehicle Type	Bumper No.	Vehicle ID No.	Engine ID No.	Engine Type	Type Oil
M60A1	H-24	9382	32739	AVDS-1790-2C	Blue
M60A1	H-31	17031	A1842	AVDS-1790-2C	Red
M60A1	H-32	6395	A1669	AVDS-1790-2D	Red
M60A1	H-33	6348	31905	AVDS-1790-2C	Yellow
M60A1	H-34	3645	A0171	AVDS-1790-2D	Yellow
M60A1	H-35	6376	35022	AVDS-1790-2D	Blue
M113A1	E-11	20842	6D167898	DDAD-6V-53	Yellow
M113A1	E-12	4119	6D6937	DDAD-6V-53	Yellow
M113A1	E-21	20857	6D68305	DDAD-6V-53	Red
M113A1	E-24	4093	6D44892	DDAD-6V-53	Red
M113A1	E-31	20884	6D168056	DDAD-6V-53	Blue
M113A1	E-32	4122	6D56918	DDAD-6V-53	Blue

Three type lubricants, coded "Yellow, Red, and Blue," were used for the test. The "Yellow" oil was a synthetic polyalphaolefin-based lubricant of a single manufacturer and batch. This oil was a qualified MIL-L-46167 product

meeting commercial SAE viscosity grade OW-20 and performance classifications SF/CD. The "Red" oil was a mineral-based lubricant meeting SAE viscosity grade 10W-30. The oil was from a single batch formulated using additive technology known to provide SF/CD performance in Grades 30 and 15W-40 products and was under evaluation in a program addressing the use of multiviscosity products in Army engine applications. The remaining lubricant, "Blue" oil, consisted of a variety of qualified Grade 30 and 50 MIL-L-2104C products obtained from Fort Bliss supplies. These oils were mineral-based lubricants of various manufacturers which would meet at least SC/CD* performance requirements. Table 2 provides a description and analytical data covering the "Yellow" and "Red" lubricants. Blue lubricant has not been included because of the variety of individual manufacturer and batch products employed during the test.

TABLE 2. DESCRIPTION OF YELLOW AND RED TEST LUBRICANTS

Description	ASTM Method	Yellow	Red
Specification		MIL-L-46167	MIL-L-2104D (Experimental)
Lubricant Type		Synthetic	Mineral
Grade		0W-20	10W-30
Properties			
Viscosity, cSt	D 445		
at 40°C		30.10	66.40
at 100°C		5.85	10.50
Viscosity Index	D 2270	142	145
TAN	D 664	2.57	2.10
TBN	D 2896	6.00	10.30
Flash Point, °C	D 92	238	202
Sulfated Ash, wt%	D 874	1.07	1.10
Elements, wt%			
Ba XRF	0.23	0.005	
Ca XRF	0.00	0.10	
Mg AA	0.09	0.09	
Zn XRF	0.12	0.13	
P XRF	0.11	0.10	
S XRF	0.55	0.58	

* Although Specification MIL-L-2104C defines oils of SC/CD performance, the majority of qualified products are either SE/CD or SF/CD quality level.

Only the engines of the test vehicles were charged with the test lubricants, although these oils are also believed satisfactory for use in the transmission and final drives.

The six M60A1 tanks were provided and operated by H Troop, 2d Squadron, 3rd ACR, and the six M113A1 APCs were provided and operated by E Troop of the same organization. Organizational maintenance consisting of minor service and repair work was performed by the maintenance sections of E and H Troops and the 2nd Squadron. If major service or repairs were required, the engine involved was removed and turned in to the 513th DSU for a replacement engine. It would then be shipped within 24 hours after its receipt to Anniston Army Depot for repair or rebuild. It was agreed in the final coordination meeting of 3 July, 1980 that any engine from a test vehicle that was evacuated to Anniston Army Depot would be tagged and cause of malfunction determined. The results would be made available to AFLRL representatives.

The pilot field test was conducted according to the test plan given in Appendix B. This test plan included procedures for initial oil installation and periodic sampling. On 25 March 1981, during a field visit by an AFLRL representative, problem areas for the participating units and AFLRL were discussed. Several changes were agreed upon to resolve these problem areas and were incorporated during Phase II of the test (25 March 81-31 October 1981). A copy of the trip report is attached as Appendix C.

III. DISCUSSION

A. Pilot Field Test at Fort Bliss, TX-Phase I(1 August 1980-24 March 1981)

On 1 August 1980, the pilot field test was begun at Ft. Bliss, Texas, utilizing the vehicles and lubricants shown in Table 1 to determine the feasibility of using multiviscosity/multiseasonal engine oils for crankcase lubrication of tactical/combat vehicles operating in very warm weather conditions.

The crankcases of the test vehicles were charged with the test lubricants as shown in Table 1. During the test, the vehicles were subjected to normal mission/training operations. No maintenance problem was reported through 1 February 1981. There was one AOAP-directed oil change for an M60A1 tank, Bumper No. H-24 in January 1981. However, prior to a 3-week field exercise to be conducted in March 1981, four engines were replaced because of "excessive dirt in the oil" as shown in Table 3.

TABLE 3. BREAKDOWN ANALYSIS OF ENGINE REPLACEMENTS-PHASE I

Bumper No.	Type Engine	Oil Used	Date	Reason for Replacement
H-24	AVDS-1790-2C	Blue	1-28 Feb 81	Excessive Dirt in Oil
H-35	AVDS-1790-2C	Blue	1-28 Feb 81	Excessive Dirt in Oil
H-32	AVDS-1790-2D	Red	1-28 Feb 81	Excessive Dirt in Oil
H-34	AVDS-1790-2D	Yellow	1-28 Feb 81	Excessive Dirt in Oil

As noted in the Ft. Carson/Ft. Lewis fleet tests, the air induction system for the AVDS/1790 engine is a problem area and was particularly troublesome in the desert environment of Ft. Bliss, TX. Because no consistent vehicle utilization data were available, no summary of operational data is presented here. Except for the AOAP-directed oil change reportedly done in January 1981, only 2 quarts of make-up oil were used. These were added to test vehicle E-12, and M113A1 vehicle with a 6V-53 engine, which used the lubricant coded yellow. Analysis of used oil samples during Phase I were considered questionable in some instances because it appeared that the oils in some of the test engines had been inadvertently mixed or replaced with other than the assigned test oils. The difficulties cited in Phase I and the questions raised by the analysis of the used oil samples prompted the Field Trip of 25 March 1981 which began Phase II.

B. Pilot Field Test at Ft. Bliss-TX, Phase II(25 March 1981-31 October 1981)

The agreements reached between the AFLRL representative and the 2nd Squadron, 3rd ACR during the liaison trip of 25 March 1981 are listed in Appendix C.

Table 4 shows the vehicles involved with identifying numbers and test oils assigned. The lubricants in Table 4 are the same oils identified in Phase I.

TABLE 4. DESCRIPTION OF TEST VEHICLES-PHASE II

Vehicle Type	Bumper No.	Vehicle Id No.**	Engine ID No.**	Type Oil
M113A1*	E-11	MSJ20842	5185028	Yellow
M113A1*	E-12	4119	6D188349	Yellow
M60A1*	E-16	7260	A2599	Yellow
M60A1*	E-17	7305	A1588	Yellow
M113A1*	E-21	MSJ20857	513904	Red
M113A1*	E-24	4116	56602	Red
M60A1*	E-26	2385	A0428	Red
M60A1*	E-27	6769	2500-1	Red
M113A1	E-31	MSJ20884	5439094	Blue
M113A1	E-32	4122	139094	Blue
M60A1	E-36	6877	91-8	Blue
M60A1	E-37	6737	23467	Blue

* Test Vehicles

** Discrepancies in Vehicle ID No. and Engine ID No. between Tables 1 and 4 were resolved by maintenance personnel in E Troop.

A hiatus in the test occurred between 25 March 1981 and 29 May 1981 due to the need to recharge the test engines with their respective test oils and an unavoidable delay in acquiring the yellow synthetic test oil in sufficient quantities to complete the test. On 29 May 1981, with two exceptions, the test engines were charged with their respective test oils.(16)

Phase II of the test was extremely important because of the six-week field exercise activities that occurred during this phase of the program. Of these weeks, four involved a continuous exercise from 20 August through 20 September 1981. Ambient temperatures reached 37.8°C (100°F), which was typical for that time of year. Sufficient oil samples were received from the test and control units to enable AFLRL to adequately analyze,

record and observe useful data concerning the chemical and physical properties of the samples. Computer printouts were received from the AOAP laboratory at the Corpus Christi Army Depot (CCAD), Corpus Christi, TX, giving backup data in wear metals and contaminants. The one major area in which comparisons could not be made under current procedures was in the presentation of viscosity data as produced by the AOAP laboratory and by the AFLRL laboratory. This is because viscosity as determined by the AOAP lab is expressed as a viscosity density product at ambient temperatures (centipoises times g/cm^3), while viscosities determined at AFLRL are arrived at through ASTM Method D 445 and are reported in centistokes. However, the trend in viscosities could be determined using either method of reporting.

Table 5 provides a summary of vehicle usage in miles traveled and oil additions in quarts for the period 29 May 1981 through 30 September 1981.

TABLE 5. SUMMARY OF VEHICLE OPERATION-PHASE II

Vehicle Type	Bumper No.	Engine Type	Miles Traveled	Oil Addition in Quarts	Miles per Qt.	Type Oil
M113A1	E-11	DDAD-6V-53	318	3	106.0	Yellow
M113A1	E-12	DDAD-6V-53	293	5	58.6	Yellow
M113A1	E-21	DDAD-6V-53	330	11	30.0	Red
M113A1	E-24	DDAD-6V-53	309	2	154.5	Red
M113A1	E-31	DDAD-6V-53	340	2	170.0	Blue
M113A1	E-32	DDAD-6V-53	130	3	43.3	Blue
M60A1	E-16	AVDS-1790-2D	292	8	36.5	Yellow
M60A1	E-17	AVDS-1790-2D	317	7	45.3	Yellow
M60A1	E-26	AVDS-1790-2D	230	4	57.5	Red
M60A1	E-27	AVDS-1790-2D	320	8	40.0	Red
M60A1	E-36	AVDS-1790-2A	297	8	37.1	Blue
M60A1	E-37	AVDS-1790-2A	314	8	39.3	Blue

The number of miles traveled by each vehicle as shown in Table 5 are not indicative of the total hours each engine was operated. Many times the vehicles sat at idle for protracted periods of time. A comparison of the data in Table 5 with the hours operation shown in Table 7 will emphasize this point. Prolonged idling of engines creates a hostile environment for

any lubricant due to incomplete combustion of fuels, with a subsequent dilution of the engine oils. It appears that, despite these operating conditions, the test lubricants performed adequately.

Table 6 shows the engine replacements and the reason for those replacements.

TABLE 6. BREAKDOWN ANALYSIS OF ENGINE REPLACEMENTS-PHASE II

Bumper No.	Type Engine	Oil Used	Date	Reason for Replacement
E-32	DDAD 6V-53	Blue	1-31 Aug 81	Faulty Water Pump
E-26	AVDS-1790-2D	Red	1-30 Sep 81	Excessive silicon and dirt
E-27	AVDS-1790-2D	Red	1-30 Sep 81	Excessive silicon and dirt

Table 7 gives the hours of operation since the last overhaul and the hours of operation since the last oil change as of 30 October 1981. There was no

TABLE 7. HOURS OF OPERATION

Vehicle Bumper No.	Since Last Overhaul	Since Last Oil Change
E-11	129	53
E-12	205	44
E-16	567	35
E-17	81	81
E-21	127	6
E-24	124	33
E-26	55	49
E-27	31	31
E-31	418	52
E-32	579	21
E-36	592	41
E-37	227	41

feasible way to determine the number of quarts of oil that would have brought the level in each crankcase to the full mark. The unit had just returned from a week in the field, and 30 October 1981 was the last day of

the test. Since the remaining test oil would be returned to AFLRL and the test engines recharged with the normal MIL-L-2104C, OE/HDO 30 or OE/HDO 50, test oils were not added to the test engines.

A final trip was made to obtain subjective information and to formally end the pilot field test.(17) Comments about the test lubricants by operating and maintenance personnel ranged from "a superior performance" to "as good as any other oil in use." Of particular importance is the decreased skepticism on the part of crew members and organizational maintenance personnel that the test oils could offer sufficient lubrication/protection for the engines during the higher ambient temperatures which prevail in the Ft. Bliss area from April through September. During the entire period of the test, there was no comment or observation about the engines overheating. This point was specifically addressed by the AFLRL representative since it had been a factor in the Ft. Carson/Ft. Lewis field tests. According to the operating personnel, there was no noticeable increase in the number of times the red warning light came on in the vehicle because of decreased oil pressure. It was believed that this might be a matter of concern when using the arctic oil. The crew members indicated that the engines with the yellow synthetic oil and the red mineral multigrade oil started easier in cool temperatures than those using the blue lubricant. Ft. Bliss, like Ft. Carson, experiences extremes in daily temperatures which can vary as much as 16.7°C (30°F).

The data generated as a result of oil analyses during Phase II were evaluated against standards for wear metal limits as established in the "Army Oil Analysis Program Laboratory Guide for Nonaeronautical Equipment".(18) The results of this evaluation are shown in Table 8. The lubricants coded "blue" show more abnormal accumulations of iron than the other two test oils. It is believed that the excess of iron content in the oils coded blue exists because of the greater number of operating hours (Table 7) by the engines using the blue oils. Maintenance practices and procedures as well as operator performance could account for other minor differences.

TABLE 8. USED OIL ANALYSES WEAR METAL AVERAGES VERSUS WEAR METAL LIMITS STANDARDS*

Qualitative Ratings			Wear Metals																													
Bumper Number	Type Engine	Oil Code	Fe				Ag				Al				Cr				Cu				Si				Sn				Ni**				Pb				Mo			
			N	M	H	A	N	M	H	A	N	M	H	A	N	M	H	A	N	M	H	A	N	M	H	A	N	M	H	A	N	M	H	A	N	M	H	A	N	M	H	A
E-11	6V-53	Yellow				●	x					+			x					+			x				x								x				x			
E-12	6V-53	Yellow	x				x				x				x							●	x				x								x				x			
E-21	6V-53	Red			+		x				x				x				x				x				x								x				x			
E-24	6V-53	Red	x				x					+			x				x				x				x								x				x			
E-31	6V-53	Blue				●	x				x				x				x				x				x								x				x			
E-32	6V-53	Blue				●	x							●				●			+			+			x									●			x			
E-16	1790-2	Yellow		+			x				x				x				x				x				x				x				x				x			
E-17	1790-2	Yellow	x				x				x				x				x				x				x				x				x				x			
E-26	1790-2	Red	x				x				x				x				x				x				x				x				x				x			
E-27	1790-2	Red				●	x				x				x				x				x				x				x				x				x			
E-36	1790-2	Blue				●	x				x						+			+			x				x				x					+			x			
E-37	1790-2	Blue				●					x					+						●	x				x											●					

NOTE: Mg does not apply to the AVDS 1790-2 engine; standards listed in the AOAP Guide do not apply to the 6V-53 engine when the metal is used as an additive.

N = Normal
M = Marginal
H = High
A = Abnormal

*Wear metal limits standards were determined by AFLRL for the U.S. Army Tank-Automotive Materiel Readiness Command and published in the "Army Oil Analysis Program Laboratory Guide for Nonaeronautical Equipment."

**Does not apply to the 6V-53 engine.

Table 9 compares used oil additive data with the levels found in the new oil samples. Since no initial data were provided for the blue oil, the used oil analyses additive data are shown for information only. No significant differences appear between additive amounts for a given oil, except that for the engines using yellow and red oils, in which there was a rather large increase for Calcium. Causes for the increases in Ca were not investigated.

Three elements were revealed by the used oil analyses as contaminants. Na and Cl appeared in the oils in very small amounts, with the exception of E-12, an M113A1 APC equipped with a 6V-53 engine. The relatively larger amount of Na in this vehicle engine oil was probably the result of a slight leak in the engine coolant system. The third element, boron, was present in insignificant amounts in all engines except E-21 and E-24, M113A1 APCs with 6V-53 engines and E-26 and E-27, M60A1 tanks with 1790-2 engines. All four of these engines were operated using the red mineral multiviscosity oil. New oil samples were taken and evaluated for content by the CCAD AOAP laboratory and by the company supplying the red oil. In both cases, a high boron content was determined to be in each sample. The representative for the company supplying the red oil attributed the boron to a refining process used in producing the oil. However, he stated that, although not considered harmful, the quantity of boron present was almost double the amount normally expected and that he would conduct an inquiry into the production process to determine the reason.

TABLE 9. USED OIL ANALYSES ADDITIVE AVERAGES VERSUS NEW OIL ADDITIVE QUANTITIES*

Bumper Number	Type Engine	Type Oil	Additives											
			Ba, wt%		Ca, wt%		Zn, wt%		Mg, wt%		P, wt%		S, wt%	
			Used	New	Used	New	Used	New	Used	New	Used	New	Used	New
E-11	6V-53	Yellow	0.15	0.23	0.10	0.00	0.11	0.12	0.04	0.09	0.09	0.11	0.78	0.55
E-12	6V-53	Yellow	0.13	0.23	0.07	0.00	0.12	0.12	0.07	0.09	0.08	0.11	0.67	0.55
E-21	6V-53	Red	<0.02	<0.005	0.11	0.10	0.11	0.13	0.07	0.09	0.08	0.10	0.65	0.58
E-24	6V-53	Red	<0.01	<0.005	0.13	0.10	0.12	0.13	0.06	0.09	0.08	0.10	0.57	0.58
E-31	6V-53	Blue	<0.01	ND	0.16	ND	0.10	ND	0.08	ND	0.07	ND	0.79	ND
E-32	6V-53	Blue	<0.01	ND	0.19	ND	0.12	ND	0.06	ND	0.06	ND	0.59	ND
E-16	1790-2	Yellow	0.13	0.23	0.09	0.00	0.13	0.12	0.07	0.09	0.08	0.11	0.49	0.55
E-17	1790-2	Yellow	0.14	0.23	0.06	0.00	0.14	0.12	0.06	0.09	0.09	0.11	0.50	0.55
E-26	1790-2	Red	0.03	<0.005	0.13	0.10	0.12	0.13	0.07	0.09	0.09	0.10	0.55	0.58
E-27	1790-2	Red	0.01	<0.005	0.16	0.10	0.13	0.13	0.06	0.09	0.08	0.10	0.62	0.58
E-36	1790-2	Blue	<0.01	ND	0.16	ND	0.11	ND	0.08	ND	0.07	ND	0.65	ND
E-37	1790-2	Blue	<0.01	ND	0.14	ND	0.12	ND	0.06	ND	0.08	ND	0.68	ND

*All elements except Mg determined by XRF; Mg determined by AA.
ND = Not Determined.

IV. CONCLUSIONS

Conclusions derived from the program include the following:

- There were no apparent differences in the high-temperature performances of the synthetic multiviscosity oil, the conventionally formulated multiviscosity mineral oil, or the MIL-L-2104C control oil.

- During this test, no abnormal increases in oil temperatures were reported.

- There was no apparent change in the engine failure/removal rate.

V. RECOMMENDATIONS

Based on information generated during this evaluation, the following actions are recommended:

- Expand the program to include all operational ordnance and engineer equipment which uses a MIL-L-2104C lubricant in one or more cavalry squadrons/self-propelled artillery battalions. Such a program could be performed as a user acceptance test for a MIL-L-2104D multiviscosity product.

- Until such a program expansion can be initiated, a limited field test should be conducted in very warm weather conditions allowing the use of the yellow synthetic oil and the red mineral oil in transmissions, final drives, and other components where MIL-L-2104C is used.

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APPENDIX A

BACKGROUND TO PILOT FIELD TEST OF MULTIVISCOSITY/SYNTHETIC ENGINE OIL IN ARMY COMBAT/TACTICAL VEHICLES

AFLRL personnel visited Ft. Bliss, TX on 8 May 1980 to effect initial coordination with the 3rd ACR of Ft. Bliss (A1)*, and an AFLRL representative made a subsequent trip on 3 July 1980 to effect final coordination of the Multiviscosity Engine Oil Pilot Field Test.(A2) The changes made to the initial Proposed Pilot Fleet Test Plan in the 8 May trip and the agreements reached as a result of the 3 July field trip are contained in Reference A3.

Initially the scope of the test was limited to eight M60A1 tanks powered by TCM AVDS 1790-2A and 1790-2C RISE engines. Four of these engines were to be charged with a multiviscosity synthetic lubricant, 5W-20 grade, and the remaining four engines were to be charged with the standard issue MIL-L-2104C OE/HDO lubricant in accordance with pertinent lubrication orders. In Phase I, the synthetic oil containers and some components on the M60A1 tanks were to be painted yellow. The MIL-L-2104C OE/HDO oil containers and some components on the remaining M60A1 tanks were to be painted blue. However, MERADCOM desired that a multiviscosity conventionally formulated mineral oil be included in the test. Thus, the scope of the test was changed, decreasing the number of M60A1 tanks from eight to six and adding six M113A1 APCs powered by 6V-53 Detroit diesel engines. Two AVDS 1790-2 engines and two 6V-53 engines were to be charged with the multiviscosity synthetic oil, 0W-20 grade, color coded yellow; two AVDS 1790-2 engines and two 6V-53 engines were to be charged with a multiviscosity conventional formulated mineral oil, 10W-30 grade, color coded red; and the remaining four engines were to be charged with the MIL-L-2104C standard issue oil, color coded blue. Both multiviscosity oils had been previously evaluated in laboratory tests at AFLRL.

Reference A3 also specified that:

1. Vehicles would be selected from only two units to facilitate control and data gathering.

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* Underscored alphanumeric designation in parentheses refer to the list of references at the end of this appendix.

2. The 3rd ACR would exercise control and security procedures which would ensure issuance of test oils only to test vehicles.

3. Follow-up procedures were formulated to determine cause of engine failure should it occur in any of the test vehicles.

In addition to these agreements, the progress report of Reference A3 also noted that the AFLRL representative of the 3 July field trip had arranged for the arrival of 165 gallons of the 0W-20 synthetic oil and 165 gallons of the experimental 10W-30 grade mineral oil at Ft. Bliss, TX. These oils were stored in the 2d Squadron POL storage area.

One other aspect of the initial program was the request for retention at Ft. Bliss of a spare AVDS-1790 engine for immediate use as a replacement test engine should one be needed.(A4) It was determined, however, that, although desirable, it would not be feasible for this action to be taken since the AVDS-1790 engine is designated as a direct exchange item. To make this policy work, any item in the system requiring major overhaul, repair, or replacement, and which is too costly to stock in large quantities must be turned in to the proper repair facility as soon as possible. A direct exchange is made by issuing a repaired or overhauled item for the failed item. At Ft. Bliss, the AVDS-1790 engine had to be turned in to the 513th DSU, which, in turn, had to ship it within 24 hours of receipt to Anniston Army Depot. There were no significant delays caused by a lack of replacement engines.

In addition to the actions taken to coordinate with the 3rd ACR, the AOAP laboratory at the CCAD agreed to provide AFLRL with oil sample analyses data on a regular basis. This information would be in addition to data developed through AFLRL analysis of oil samples received from the 3rd ACR. These oil samples would be taken at the same time samples for the AOAP laboratory were taken. Assurance was received from the 3rd ACR Regimental Materiel Management Office that the test units had sufficient oil sampling equipment on hand.

The test was conducted between 1 August 1980 and 31 October 1981. Because of difficulties encountered in the first months of the test due to unforseen operational practices and a turn-over in military personnel initially involved in the test, two separate phases of the test evolved. Phase I includes the time period 1 August 1980 through 24 March 1981, and Phase II includes the time period 25 March 1981 through 31 October 1981.

APPENDIX REFERENCES

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APPENDIX B

PROPOSED PILOT FIELD TEST PLAN FOR FT. BLISS, TX

PROPOSED
PILOT FIELD TEST PLAN*
FOR FT. BLISS, TX
(TO COMMENCE 1QFY80 AND FINISH 4QFY80)

Purpose

To determine feasibility of using synthetic engine oils in combat/tactical vehicles, with particular emphasis on performance in a high-temperature environment.

Scope

Six M60 vehicles, powered by TCM AVDS 1790-2A and 1790-2C RISE engines and six M113 vehicles powered by DDAD 6V53 engines, will be subjected to normal mission/training operations. Four vehicles will use a synthetic engine oil, 0W-20 grade, provided by USAMERADCOM/AFLRL, and four vehicles will use a conventionally formulated, 10W-30 grade oil also provided by USAMERADCOM/AFLRL. The remaining four vehicles will use MIL-L-2104C OE/HDO oil as a "baseline" oil.

Procedure

I. Pretest Vehicle and Engine Inspection/Preparation

A. Inspection

Review engines' operational/maintenance history for twelve selected vehicles. If a potential problem area is noted for a given engine, the engine will be replaced with another provided by DIO.

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* As modified by the initial coordination visit 8 May, 1980 and the final coordination visit of 3 July, 1980.

B. Preparation

Before draining the original MIL-L-2104C oil, record oil pressure under fully warmed-up operating conditions for each engine. Drain the MIL-L-2104C single-grade engine oil from the eight test vehicle engines while the oil is warm. Retain a 12-oz sample from each engine. Change engine oil filters and charge four engines (two of the model AVDS 1790-2 engines and two of the DDAD 6V-53) with the synthetic test oil, and four engines (two of the model AVDS 1790-2 and two of the 6V-53) with the conventionally formulated mineral oil, 10W-30 grade.

Warm up the engines and obtain a 4-oz sample from each engine using a suitable syringe and tubing to extract the oil through the dipstick tube. Repeat the oil pressure measurement for all eight engines in the same manner as described above. The oil samples must be identified with same information described in Section IIC.

C. Color Coding Lubricants/Vehicles

The drums of test oil will be color-coded as yellow (synthetic), red (mineral, multiviscosity), or blue (MIL-L-2104C OE/HDO). The test vehicles will also be identified and color-coded by painting the oil filler cap, oil filler cover, dipstick access cover, and dipstick handle, red or yellow as appropriate. Other labels in the vehicle will be considered and provided where appropriate.

II. Lubricant Testing

A. Duration

Subject the test vehicles to normal mission/training operation through 4QFY80. No engine oil change is to be made except as covered in Section III.

B. Information To Be Recorded

The following information should be maintained during the course of the test in the form of a "Test Diary":

1. Oil Consumption: Date, hours, miles, quantity added.
2. Fuel Consumption: Date, hours, miles, quantity added.
3. Engine Maintenance: Date, action, reason; i.e., scheduled or unscheduled.
4. Observed Differences in Engine Power/Performance (i.e., good, better or worse; runs "cooler," runs hotter, overheats, etc.).
5. Indications, if any, of oil leakage, and continuous observations of such leakage as long as it continues.

NOTE: For Items 4 and 5, observations of both the operating crew and maintenance personnel should be made and recorded in the Test Diary. Comments relating to any of the above items or any unusual operations which may be of significance should also be recorded in the Test Diary.

C. Oil Sampling and Identification

After the initial oil sample is taken at start of test, a 4-oz sample of warm oil should be taken from the engine every month or 25 hours of engine operation (normal AOAP sampling procedure). Also, these samples are in addition to the AOAP requirement. Each sample must be identified as follows:

1. Vehicle USA Number
2. Engine S/N
3. Vehicle Miles (total on vehicle)
4. Engine Hours (total on vehicle)
5. Date of Sample

Samples should be mailed to:

U.S. Army Fuels and Lubricants Research Laboratory
c/o Southwest Research Institute, Attn: Ruben Alvarez
P.O. Box 28510
San Antonio, Texas 78284

D. Conclusion of Test

On completion of test, a final oil sample of two gallons should be taken from each engine when the oil is drained. This sample should also be identified in the same manner as the other samples. All oil filters from each engine should be removed, packaged, and marked in the same manner as the final oil drain sample.

III. Supplementary Information

A. Lower Oil Pressure

It is possible that due to its lower viscosity, the MIL-L-46167 synthetic engine lubricant will cause the engine-oil low pressure light/alarm to be activated during idle speeds. Operating personnel should be advised of this condition and that the four engines using the synthetic oil might operate at lower oil pressure over the entire speed range.

B. Oil Changes

Since it is the intention of this field test to determine if the engine oil can help reduce routine maintenance and improve vehicle readiness, there will be no oil changes during the test. Exceptions to the above are as follows:

1. If the DIO, other responsible maintenance organization, or the Unit Commander decides that the four vehicles using MIL-L-2104 OE/HDO should be changed to the next higher viscosity grade due to expected temperature warming, then in accordance with the LO, the engine oil will be changed. However, it would be highly desirable to use only one OE/HDO

viscosity grade the year around and change the oil only if its condition indicates a change is needed.

2. If laboratory analysis of the MIL-L-2104C OE/HDO or the synthetic engine oil indicates an oil change is merited, then notification for a change will be issued.

C. Items To Be Finalized

- Identification of engine maintenance organization
- Identification of the test monitor at Ft. Bliss
- Current viscosity grade usage for MIL-L-2104C
- Is AOAP laboratory support available?
- Responsibilities of Ft. Bliss Test Monitor
- Selection of eight test vehicles
- Possible expansion of program to include the transmissions and final drives in the four test vehicles
- Possible extension of program beyond one year

APPENDIX C

TRIP REPORT ON LIAISON VISIT BY AFLRL REPRESENTATIVE TO FT. BLISS, TX

TRIP REPORT

Walt Butler, Jr.
Fort Bliss, Texas

Subject: Liaison visit to 3rd Armored Cavalry Regiment concerning the Field Test Program

Initial contact was made with Sgt. Toomey, the Regimental S-4 Sgt. and Lt. Holstein, the 2nd Sqd Maintenance Officer, at the Regimental S-4 office. After introductions, Lt. Holstein and I went to the 2nd Sqdn maintenance shop and discussed our views about the Fleet Test Program.

My comments and queries were as follows:

a. AFLRL did not receive oil samples on a regular basis.

b. AFLRL did not receive subjective comments with oil samples as to how the engines performed with the test lubricants.

c. Were the oil samples received actually from the test engine instead of, perhaps, a transmission or final drive?

d. What actions were taken which caused changes in oil sample results? (Engine rebuild?, oil added?, oil changed?)

Lt. Holstein offered the following observations:

a. The using units had problems about 60 to 90 days prior to the visit because rebuilt engines were being charged with non-test oil before being returned to the units.

b. There is concern that the 0W-20 synthetic multiviscosity and 10W-30 mineral multiviscosity engine oils will not hold up during high summer temperatures. (Last summer the temperature was stated to have gone up to 118°F).

c. The program is unmanageable because there were two units (E and H Troops) involved as well as one and one-half platoons in each troop. Since Troops and Platoons are frequently miles apart on exercises, the amount of test lubricants on hand are inadequate to be issued on a separate basis.

Together, Lt. Holstein and I visited the 2nd Sqdn POL dump where it was immediately apparent that the drums of test oil last shipped to the unit were unopened and indistinguishable from other drums stored with them. Further, discussions with the crews of the test vehicles confirmed that in the absence of the test lubricants, they used any available, appropriate oil (OE/HDO-30 in the winter and OE/HDO-50 in the summer). Obviously, this negated all oil sample results to date.

Lt. Holstein's recommendations for changes in the program which will make the test work are as follows:

a. Select all the test vehicles from one Troop (E Troop was selected).

b. Issue test oil directly to each test platoon rather than keep them in the POL Dump.

c. Paint the test oil drums with the following colors:

(1) 0W-20 synthetic-multiviscosity oil-yellow
(2) 10W-30 mineral-multiviscosity oil-red
(3) MIL-L-2104C-OE/HDO 30 or OE/HDO 50-blue

d. He will also have the oil cans and dip stick tube for each test vehicle painted with corresponding colors to match the test oil used in the vehicle engine.

e. Lt. Holstein will establish an SOP for the program as it pertains to the gathering of the oil samples (when, by whom, how much) and its forwarding to USAFLRL. Since the program will essentially be starting from scratch, sampling and initial procedures will be followed as stated in the initial coordination meetings.

f. Information accompanying oil samples will include:

(1) Vehicle bumper number
(2) Engine ID number
(3) Vehicle ID number
(4) Engine hours (total hours)
(5) Date of sample
(6) Hours/miles since last oil change
(7) Oil added since last sample
(8) Vehicle miles (total miles)
(9) Subjective comments of crew or maintenance personnel

g. Subsequent oil samples will be taken and forwarded the first week in each month.

h. Final test samples will be taken and forwarded as initially set up in the initial coordination meetings.

i. Lt. Holstein estimated a minimum of 250 gallons of each test oil should be on hand initially and replenished as required each 30 days until usage becomes normal, then replenish as needed.

By mutual agreement, it was decided that USAFLRL would supply 250 gallons of each test oil to the 2nd Sqdn for further issue to E Troop which has the test platoons. The target date for getting the oil to Ft. Bliss will be 11 April 1981 which is the date E Troop returns from the field.

USAFLRL will ensure that the test oils are maintained as required.

USAFLRL will request exceptions be granted E Troop, 2nd Sqdn, so that they will not be penalized during scheduled inspections for painting the oil cans and dip stick tubes the identifying test colors.

USAFLRL will request authorization to send qualified personnel to Ft. Bliss for the purpose of examining any test engine which is believed to have failed because of test oil inadequacies. Lt. Holstein will call, collect, to Walt Butler, 512-684-5111-extension 3128 when such an engine has been turned into the 513th DSU.

A list of designated test vehicles is attached hereto as Enclosure 1.

It is believed that the above procedure, when instituted, will yield the data required to make the Fleet Test Program successful. This belief is further enhanced by the cooperation and positive attitudes exhibited by Lt. Holstein and Sgt. Toomey.

Bumper No.	Vehicle Type	Vehicle ID No.	Engine ID No.	Type Oil
E-11	M113A1	MSJ-20842	5185028	0W-20 Synthetic Oil
E-12	M113A1	4119	6D81720	0W-20 Synthetic Oil
E-21	M113A1	MSJ-20857	513904	10W-30 Mineral Oil
E-24	M113A1	H116	56602	10W-30 Mineral Oil
E-31	M113A1	MSJ-20884	5439094	MIL-L-2104C OE/HDO**
E-32	M113A1	4122	139094	MIL-L-2104C OE/HDO
E-16	M60A1	7260	*	0W-20 Synthetic Oil
E-17	M60A1	7305	*	0W-20 Synthetic Oil
E-26	M60A1	2385	*	10W-30 Mineral Oil
E-27	M60A1	6769	*	10W-30 Mineral Oil
E-36	M60A1	6877	*	MIL-L-2104C OE/HDO
E-37	M60A1	6737	23467	MIL-L-2104C OE/HDO

* Not available at time of visit.
** OE/HDO 30 or OE/HDO 50 as determined by the pertinent lube order.

Enclosure 1

LIST OF ACRONYMS AND ABBREVIATIONS

MERADCOM	-	United States Army Mobility Equipment Research and Development Command
APG PD-1	-	Aberdeen Proving Grounds Purchase Description No. 1
AFLRL	-	Army Fuels and Lubricants Research Laboratory
AOAP	-	Army Oil Analysis Program
R/R	-	Remove and Repair
DIO	-	Director of Industrial Operations
CCAD	-	Corpus Christi Army Depot
ACR	-	Armored Cavalry Regiment
TCM	-	Teledyne Continental Motors
DSU	-	Direct Support Unit
APC	-	Armored Personnel Carrier
ID NO.	-	Identification Number
POL	-	Petroleum, Oil and Lubricants
DDAD	-	Detroit Diesel Allison Division
RISE	-	Reliability Improved Selected Equipment
XRF	-	X-Ray Fluorescence
AA	-	Atomic Absorption
USATECOM	-	US Army Test and Evaluation Command
USAATC	-	US Army Arctic Test Center

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DRSTA-M 1
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ST LOUIS MO 63120

CDR
US ARMY FORCES COMMAND
ATTN: AFLG-REG 1
AFLG-POP 1
FORT MCPHERSON GA 30330

CDR
US ARMY ABERDEEN PROVING GROUND
ATTN: STEAP-MT 1
STEAP-MT-U (MR DEAVER) 1
ABERDEEN PROVING GROUND MD 21005

CDR
US ARMY YUMA PROVING GROUND
ATTN: STEYP-MLS-M (MR DOEBBLER) 1
YUMA AZ 85364

PROJ MGR, ABRAMS TANK SYS
ATTN: DRCPM-GCM-S 1
DRCPM-GCM-LF (MAJ SIKES) 1
WARREN MI 48090

PROJ MGR, FIGHTING VEHICLE SYS
ATTN: DRCPM-FVS-SE 1
WARREN MI 48090

PROJ MGR, M60 TANK DEVELOPMENT
USMC-LNO, MAJ. VARELLA 1
US ARMY TANK-AUTOMOTIVE CMD (TACOM)
WARREN MI 48090

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WARREN MI 48090

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SPRINGFIELD VA 22150

PROJ OFF, AMPHIBIOUS AND WATER
CRAFT
ATTN: DRCOP-AWC-R 1
4300 GOODFELLOW BLVD
ST LOUIS MO 63120

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US ARMY EUROPE & SEVENTH ARMY
ATTN: AEAGC-FMD 1
AEAGD-TE 1
APO NY 09403

PROJ MGR, PATRIOT PROJ OFC
ATTN: DRCPM-MD-T-G 1
US ARMY DARCOM
REDSTONE ARSENAL AL 35809

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THEATER ARMY MATERIAL MGMT
CENTER (200TH)
DIRECTORATE FOR PETROL MGMT
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DRXRO-CB (DR GHIRARDELLI) 1
DRXRO-CB (DR MANN) 1
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RSCH TRIANGLE PARK NC 27709

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MAIL STP 207-5
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105TH S & T BATTALION
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TOBYHANNA PA 18466

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US ARMY MATERIALS & MECHANICS RSCH CTR
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CHAMBERSBURG PA 17201

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US ARMY WATERVLIET ARSENAL
ATTN: SARWY-RDD 1
WATERVLIET NY 12189

CDR
US ARMY LEA
ATTN: DALO-LEP 1
NEW CUMBERLAND ARMY DEPOT
NEW CUMBERLAND PA 17070

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BLDG 247, DEFENSE DEPOT TRACY
TRACY CA 95376

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US ARMY FOREIGN SCIENCE & TECH CENTER
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DRXST-BA 1
FEDERAL BLDG
CHARLOTTESVILLE VA 22901

CDR
DARCOM MATERIEL READINESS SUPPORT ACTIVITY (MRSA)
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LEXINGTON KY 40511

HQ, US ARMY T&E COMMAND
ATTN: DRSTE-TO-O 1
DRSTE-CT 1
ABERDEEN PROVING GROUND MD 21005

HQ, US ARMY ARMAMENT R&D CMD
ATTN: DRDAR-LC 1
DRDAR-SC 1
DRDAR-AC 1
DRDAR-QA 1
DOVER NJ 07801

HQ, US ARMY TROOP SUPPORT & AVIATION MATERIAL READINESS COMMAND
ATTN: DRSTS-MEG (2) 1
DRSTS-WJ (LTC FOSTER) 1
DRSTS-S 1
4300 GOODFELLOW BLVD
ST LOUIS MO 63120

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ATTN: CERL-EM 1
CERL-ZT 1
CERL-EH 1
P O BOX 4005
CHAMPAIGN IL 61820

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BALLISTIC RESEARCH LAB
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DRDAR-BLI 1
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HQ
US ARMY TRAINING & DOCTRINE CMD
ATTN: ATCD-S (LTC LESKO) 1
FORT MONROE VA 23651

DIRECTOR
US ARMY RSCH & TECH LAB (AVRADCOM)
PROPULSION LABORATORY
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21000 BROOKPARK ROAD
CLEVELAND OH 44135

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US ARMY NATICK RES & DEV LAB
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US ARMY TRANSPORTATION SCHOOL
ATTN: ATSP-CD-MS 1
FORT EUSTIS VA 23604

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US ARMY QUARTERMASTER SCHOOL
ATTN: ATSM-CD (COL VOLPE) 1
ATSM-TD 1
ATSM-DTP 1
FORT LEE VA 23801

HQ, US ARMY ARMOR CENTER
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FORT KNOX KY 40121

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ATTN: AFZB-KE-J 1
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FORT CAMPBELL KY 42223

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ACTIVITY
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FORT LEAVENWORTH KA 66027

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ATCL-C 1
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CDR
US ARMY FIELD ARTILLERY SCHOOL
ATTN: ATSF-CD 1
FORT SILL OK 73503

CDR
US ARMY ORDNANCE CTR & SCHOOL
ATTN: ATSL-CTD-MS 1
ABERDEEN PROVING GROUND MD 21005

CDR
US ARMY ENGINEER SCHOOL
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ATZA-CDM
ATZA-CDD
FORT BELVOIR VA 22060

CDR
US ARMY INFANTRY SCHOOL
ATTN: ATSH-CD-MS-M 1
FORT BENNING GA 31905

CDR
US ARMY MISSILE CMD
ATTN: DRSMI-O 1
DRSMI-R 1
DRSMI-D 1
REDSTONE ARSENAL AL 35809

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US ARMY AVIATION CTR & FT RUCKER
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FORT RUCKER AL 36362

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ATTN: DRCPM-M60-E 1
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ATZK-AE-CV 1
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ASSISTANCE OFFICE, FORSCOM
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TRENTON NJ 06828

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JOINT OIL ANALYSIS PROGRAM -
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BLDG 780
NAVAL AIR STATION
PENSACOLA FL 32508

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LMM/3 (MAJ WESTERN) 1
WASHINGTON DC 20380

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NAVAL AIR DEVELOPMENT CTR
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WARMINSTER PA 18974

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NAVAL RESEARCH LABORATORY
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ALEXANDRIA VA 22322

CHIEF OF NAVAL RESEARCH
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ARLINGTON VA 22217

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& EDUCATION COMMAND
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QUANTICO VA 22134

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MAT-08E (MR ZIEM) 1
CP6, RM 606
WASHINGTON DC 20360

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NAVY PETROLEUM OFC
ATTN: CODE 40 1
CAMERON STATION
ALEXANDRIA VA 22314

CDR
MARINE CORPS LOGISTICS SUPPORT
BASE ATLANTIC
ATTN: CODE P841 1
ALBANY GA 31704

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WASHINGTON DC 20330

HQ AIR FORCE SYSTEMS CMD
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ANDREWS AFB MD 20334

CDR
US AIR FORCE WRIGHT AERONAUTICAL LAB
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AFWAL/MLSE (MR MORRIS) 1
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SAALC/MMPRR 1
KELLY AIR FORCE BASE TX 78241

CDR
WARNER ROBINS AIR LOGISTIC CTR
ATTN WR-ALC/MMIRAB-1 (MR GRAHAM) 1
ROBINS AFB GA 31098

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USAF 3902 TRANSPORTATION SQUADRON
ATTN: LGTVP (MR VAUGHN) 1
OFFUTT AIR FORCE BASE NE 68113

CDR
HQ 3RD USAF
ATTN: LGSF (MR PINZOLA) 1
APO NEW YORK 09127

OTHER GOVERNMENT AGENCIES

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LEWIS RESEARCH CENTER
MAIL STOP 5420
(ATTN: MR. GROBMAN) 1
CLEVELAND OH 44135

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
VEHICLE SYSTEMS AND ALTERNATE FUELS PROJECT OFFICE
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LEWIS RESEARCH CENTER
CLEVELAND OH 44135

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FORRESTAL BLDG.
1000 INDEPENDENCE AVE., SW
WASHINGTON DC 20585

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
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800 INDEPENDENCE AVE, SW
WASHINGTON DC 20590

US DEPARTMENT OF ENERGY
CE-1312, GB-096
ATTN: MR ECKLUND 1
FORRESTAL BLDG.
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WASHINGTON DC 20585

US DEPARTMENT OF ENERGY
BARTLESVILLE ENERGY RSCH CTR
DIV OF PROCESSING & THERMO RES 1
DIV OF UTILIZATION RES 1
BOX 1398
BARTLESVILLE OK 74003

ENVIRONMENTAL PROTECTION AGCY
OFFICE OF MOBILE SOURCES
MAIL CODE ANR-455
(MR. G. KITTREDGE) 1
401 M ST., SW
WASHINGTON DC 20460

US DEPARTMENT OF TRANSPORTATION
ATTN: AIRCRAFT DESIGN CRITERIA BRANCH 2
FEDERAL AVIATION ADMIN
2100 2ND ST SW
WASHINGTON DC 20590

DIRECTOR
NATL MAINTENANCE TECH SUPPORT CTR 2
US POSTAL SERVICE
NORMAN OK 73069

SCIENCE & TECH INFO FACILITY
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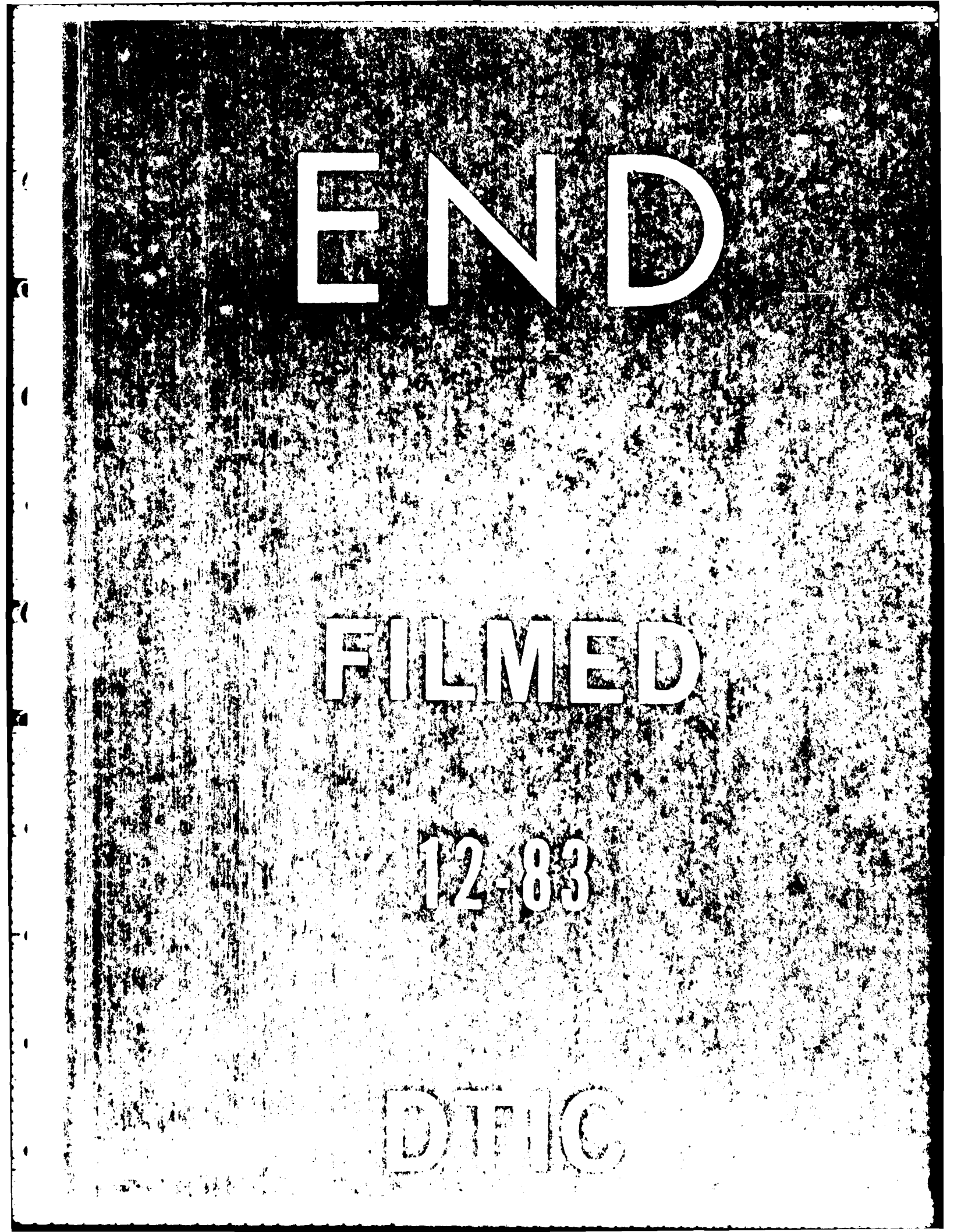
BALTIMORE/WASH INT AIRPORT MD 21240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